I. Introduction to OPTON's non-contact, whole-field, 3D Moire measurement machine series

BACK

1. Background to 3 dimensional (3D) image recognition based on new Moire method

The algorithm of Moire 3D camera is based on the paper, "Fourier Transform profilometry for the automatic measurement of 3-D object shapes" , published by Prof. Takeda of University of Electrocommunications in 1982. OPTON's measurement systems are further developed and commercialized system of the above paper. In Japan, few universities are undertaking research on this technique. Overseas, it appears that Carl Zeiss (Germany) and Lockheed Martin (US) are undertaking research, however up to now there are no commercialized system available on the market.

(1) The components of optical sensor head

The components of an optical sensor head that acquires images, which are the base of 3D calculation, are shown in Fig. 1-1. A grating pattern is projected from a grating projector, and then the deformed grating pattern on the surface to be measured is taken into a computer via a CCD camera. There is an angle between the axes of the CCD camera and the projector. Since this layout can improve the contrast of grating images and reduce the influence of the lens distortion. In addition, 3 laser pointers are used for auto-focusing of the camera, and a white light lamp is utilized for illuminating ink lines and reference marks. As an option, an optical uniaxial point measurement sensor can be included for replacing contact type probe to measure deep holes. Finally, a grating shifting mechanism can be utilized to improve data spatial resolution. All the components are listed in Table 1-1.

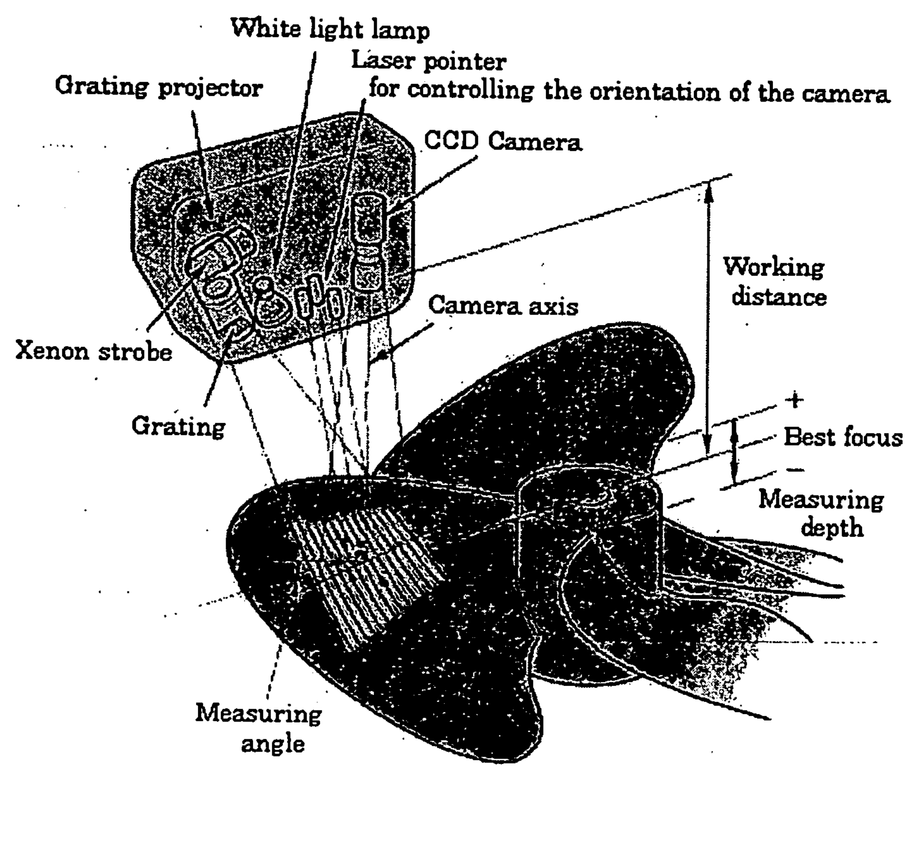


Fig 1-1 the components of sensor head.

Components	Purpose	Category	Usage
CCD camera	To digitize the grating images and general B/W images on the object. Be able to use for moving objects with improved shutter speed.	monochrome cameras	General 3D measurement
		color cameras	shape as well as color measur (CG input)
		high resolution cameras	wide field/high resolution measurement
		high-speed cameras	high-speed measurement
Grating projector	To project grating pattern on the object	Strobe lighting	general 3d measurement
		Laser lighting	Wide field measurement
Laser pointer for controlling the orientation of the camera	With respect to the surface to be measured, to control the position and orientation of the sensor head automatically	1-pointer type	Control the working distance
		3-pointer type	Control the working distance a as the orientation
White light lamp	To illuminate the object	Halogen lighting	Character line, ink line and ref mark measurements
Optical probe for uniaxial point measurement	one point 3D measurement	laser uniaxial probe	deep hole measurement and compatible with touch probe

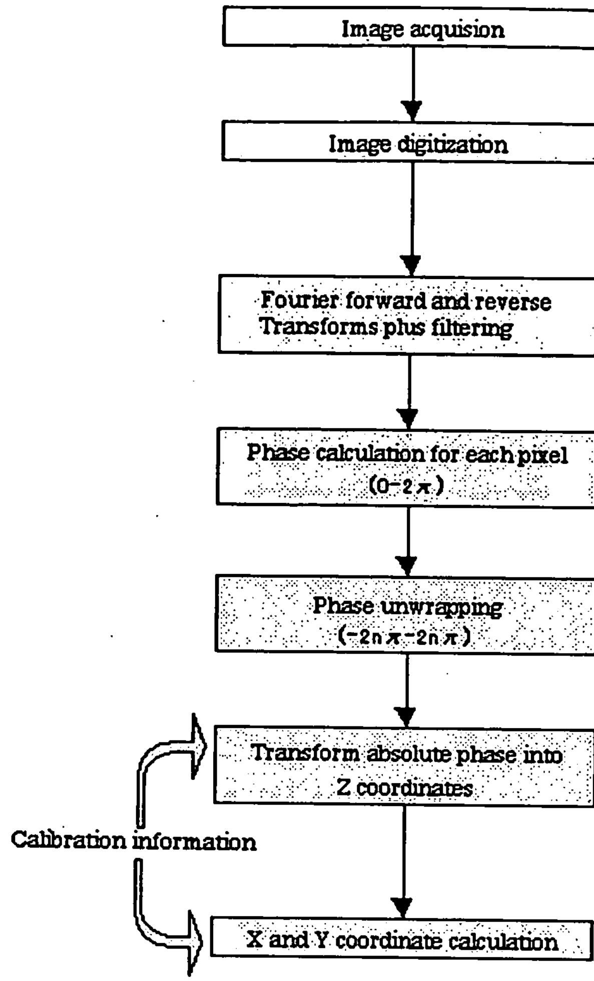
Table 1-1 the components of sensor head.

(2) Measurement

A grating pattern is projected on the surface to be measured. The projection lighting is provided by the light source of the projector. The original grating pattern is deformed along the curved surface. Then this deformed grating pattern is taken into a computer via a CCD camera and saved as a digital image.

(3) Algorithm

If the surface to be measured is a flat surface located at a reference position, say the best focus position, the deformed grating is an image of parallel straight lines with certain pitch. However, if the surface is not at the reference position or the surface is not flat, the pitch of the grating will change or the grating lines are not straight lines any more. If we look at the change of light intensity of the grating image, the 1st image is a reference wave with certain frequency, and the 2nd image is a deformed wave with its phase modulated. New Moire method calculates the phase difference between the reference and deformed waves for each individual pixel of the CCD camera. By using a unique equation the depth (Z coordinate) is obtained, then X and Y coordinates as shown in Fig.1-2. Prof. Takeda's paper provides the fundamental base for the algorithm, however the coordinates calculated here are absolute values. Also, the following are enhanced and commercialized: calibration and analysis of the grating pattern.
Generally, if there are too many points in one measurement, the accuracy will be worse. However, one can improve the accuracy by conducting a software calibration based on this big set of points. For example, point measurement and line measurement techniques have less information to decide the camera parameters. Their accuracy is based on the camera. For OPTON, it's possible to decide the mechanical and camera parameters separately since there is a surface we can use.



To take an image of the grating generated by the projector on the surface to be measured.

To digitize the analog image and save it in the computer by the CCD camera's A/D transform.

To separate different frequency component

by Fourier transform.

To calculate

the relative phase difference
with respect to the reference sine wave.

To unfold the relative phase into the absolute phase
by using its continuity.

To calculate the Z coordinates from absolute phase information
by using the calibration results.

To calculate X and Y coordinates by using the Z
and calibration information.

Fig.1-2 Algorithm diagram for New Moire method.